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Review on Diagnosis of Electricity Transmission lines using Detection, Classification and Localization of Defects

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Abstract – **The main objective of this paper is to study of the diagnosis of electricity transmission lines. Detection, classification and localization of defects were carried out using artificial neural networks (ANN) based on two different applications: a simple three-phase transmission line and a double circuit transmission line.**

The proposed method uses voltage and current signals at both ends of the line. The models of the two applications were developed with the MATLAB / Simulink software.

The effects of the variations of the parameters of the electrical network, for example: the fault resistance, the fault type and the fault distance have been studied and their impact on the performance of the ANN based protection system has been determined.

Keywords – **ANN, FL, IEC, SVM.**

I. Introduction

Electric power transmission lines are an essential part of an electric. The safety of transport networks will become one of the major challenges of the future. The economic and societal impacts of major incidents [1]. Diagnosis detection, classification and localization with the rapid elimination of defects are the main factors for satisfactory operation of an electrical network. When a fault occurs on a power transmission line, it is very important to detect and identify the types and exact location of defects. This will reduce the time required to repair the damage caused by this defect and improve reliability and continuity of service. The diagnosis of energy transmission lines has always been a well-known topic studied for a long time. However, this problem has become very important nowadays. Many techniques have been proposed and applied to analyze the different types of defects on electric transmission lines.

Perspectives that may constitute the continuation of this work.

II. Defect Analysis Protection and Techniques in the Electric Networks

As the aim of the different methods used in the analysis of defects appear on the power transmission lines is protection, we will introduce some basic concepts related to protection in electrical networks. Then we go present some techniques used in diagnosis (detection, classification and localization of the defects) of the lines of transport of the electric energy.

Electrical Network Protections

The International Electro-technical International Commission (IEC) defines protection as provisions for the detection of defects and abnormal situations in networks, in order to trigger one or more circuit breakers and, if necessary, signaling commands [2].

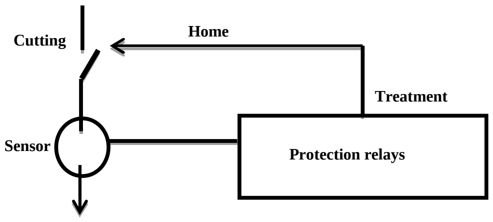

Figure 1: Block diagram of an electrical protection

Different Elements of an Electrical Protection System

An electrical protection system consists of the following elements [3]:

- Measurement sensors-current-voltage-supply-information necessary for the detection of defects.
- Protection relays, which continuously monitor the electrical condition of the network and generate control commands to the trigger circuit.
- Circuit breakers: circuit breakers, fuse switches, fuse contactors.

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III. Methods Used in Diagnosing the Transmission Lines of Electrical Energy

The diagnosis of power transmission lines consists of three essential steps represented in Figure 2. The protection function is carried out by relays or multifunction devices, which constantly compare the electrical variables of the network with adjustable thresholds. Depending on the type of protection, the quantities measured by the sensors can be: current, voltage, frequency and the calculated quantities can then be: powers, impedances. When the measurement exceeds the threshold, protection gives orders for action to open the circuit breaker [3].

Figure 2: Diagnosis of power transmission lines

Detection Techniques

There are several methods of detection we quote the following methods [4]:

- The method presented in the references [4] is based on the comparison between two successive samples of the same signal (current or voltage). When the difference between them reaches a predetermined threshold, it is directly concluded that there is a fault on the phase which corresponds to the signal.
- When the fault current of a phase is different from zero, it is concluded directly that this line is the seat of a fault which can be detected by using the indicator T_n computed from the current samples from the two ends of The line [5], the values of T_n are compared with the predetermined value T for the system in the healthy state, if the value of T_n is greater than T, so the line is in default.
- Intelligent methods have been widely used in this field, including detection by arrays of artificial neurons, expert systems, fuzzy logic [6] [7] [8] [9] [10].
- Detection by the wavelet method [11] [12].

Classification Techniques

Several methods have been used to classify or identify the type of defects [4] i.e. single-phase, two-phase or three-phase. Among these methods we quote a method based on the computation of the indicators $J_{n,m}$ $(m = a, b, , c, g)$ in the healthy state before defect and after defect. According to this method, the classification of defects can be made by comparing between the new values and the predetermined values [7].

Classification by Intelligent Algorithms

Classification by ANN: in the area of classification of defects, the use of ANN is very advantageous compared to other algorithms [10].
Classification by Fuzzy Logic: Fuzzy Logic (FL) has been applied by several researchers such as [13] and [14], for the classification of defects occurring in the overhead.

Classification by Combined Intelligent Methods

Combination ANN-FL: Because of the variety of problems encountered in electrical networks, several researchers have tried to combine the ANN and the FL. This combination differs from one job to another: fuzzy logic is used to optimize the learning parameters of ANN and improve the output representing the type of fault. An alternative approach is to use Fuzzy neurons (e.g., fuzzy neuron input and non-fuzzy or non-fuzzy input and blurred weights) [15].
Combination ANN-GA: Genetic algorithms (GA) are also applied for the optimization of neural network inputs and optimization of ANN synaptic weights.
Combination ANN-FL-GA: Other hybrid methods of combining the three intelligent systems (FL, ANN, GA) have been applied with mixed results.

Classification by the Wavelet Method

Based on the comparison of the different energy levels of the faults, we can easily differentiate the types of faults that are produced on the transmission line.

Location Techniques

Locating or finding the exact location of the defect will reduce the time required to repair the damage caused by the fault and improve the performance imposed by the power grids [10]. The localization of faults on transmission lines has always been a well-known topic for quite some time nowadays, several proposed algorithms serve to locate apparent defects in electrical networks. The following approaches can be distinguished:
First approach: These algorithms are the most widespread and are based on the use of steady-state phasors, calculated from data from one or both ends of the line.
Second approach: These algorithms based mainly on the use of differential equations in the model of the transport network.

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Third approach: These algorithms use the wave propagation principle which offers considerable advantages, especially for long lines.
Fourth Approach: These algorithms are based on the use of artificial intelligence methods.

Phaser Approach

This method is based on the estimation of the steady-state state phasors by means of the data of one or two ends. The phase shifter is a complex number which characterizes a period of a given signal and which can be estimated by several methods:

- Fourier analysis.
- Method of least squares.
- Prony method.
- Kalman filter method.

Method of Differential Equations

This method can be applied to two different models of the transport line:

- Model with concentrated parameters (lumped parameter model).
- Distributed parameter model (distributed parameter model).

Model with Concentrated Parameters: In this model the conductance g, the capacitance c of the line are neglected, we can express the partial derivative of the current $i(t)$ with respect to the position x by the following equation:

$$V_x(t) - V_s(t) = xri(t) = +lx\left[\frac{di(t)}{dt}\right] \quad (1)$$

With:
$V_s(t)$: Voltage at the end of the line.
$V_x(t)$: Voltage at position x of the line.
$i(t)$: Current measured on the line.

Approach Based on Artificial Intelligence

We cite here the following methods [9]:

- Techniques of expert systems (SXP).
- The fuzzy logic (LF).
- Artificial neural networks (ANN) [16].

IV. Application of Conventional Methods for the Diagnosis of Transport Lines

This subsection study and apply two conventional methods for the diagnosis of transmission lines. It will first apply the wavelet method for the detection and classification of defects, then it will use the phasors method for the localization of the defects.

Wavelet Method

The Fourier Transform represents an inevitable reference for any application in the field of signal processing. It allows to explore the frequency composition of the signal and its properties to apply filtering operators to it. Very early in the history of signal processing, it appeared that this Fourier decomposition was not always satisfactory and the first transformation into wavelets is proposed by Haar. The wavelet transform replaces the sinusoid of the Fourier transform by a family of translations and dilations of the same function, the wavelet. The parameters of translation and dilation make it possible to locate the information in a signal by representing it at different levels of detail ranging from a coarse and global approximation to more precise and more localized representations.
A wavelet is a function that oscillates like a wave but is rapidly attenuated hence its name wavelet which means small irregular and asymmetric wave of the effectively limited duration that has an average value equal to zero. It is localized both in time and frequency and allows to define by translation in time and dilation in scale, a family of analyzing functions. Wavelets are considered as a mathematical "zoom" to describe the properties of a signal at several time scales simultaneously.

Wavelet Analysis Techniques

Wavelet analysis is a signal processing tool that is very useful for analyzing a signal, it allows the decomposition of a signal in different resolution levels and the basic concept of this method is to choose an appropriate wavelet (And then perform the analysis using a family (Haar, Daubechies, Symlet, Coiflet, biorthogonal, Meyer, Morlet, etc.). Compared to traditional Fourier analysis, based on a global signal approach, integrations are made of minus infinity a plus infinity, and the temporal aspects of X (t) disappear in X (w). The transient parts of the signals are virtually impossible to detect using X (w). Therefore, wavelet transformation is a suitable tool for analyzing rapid changes with good temporal and frequency resolution, and with its efficient analysis of high frequencies and short-term variations, it allows a safe and rapid knowledge of the defect and Unlike Fourier analysis, wavelet transformation provides temporary time and frequency information divided into a few levels (details). Therefore, proposed direct applications are focused on the completion of detection and Classification and fault localization algorithms [17].
The voltages and passing currents during the fault bear the high frequency harmonics which disseminate important information concerning the type and location of fault.
Wavelets can be very effectively used by analyzing the phenomenon of transient fault signals. Multi-resolution analysis is one of the tools of discrete

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wavelet transformation, which decomposes the original signal into a low-frequency signal called approximations (A) and high-frequency signals called details (D). The important elements in analyzing the transient signal using the wavelet transform must choose the mother wavelet and decide the number of multiple levels of decomposition [18].

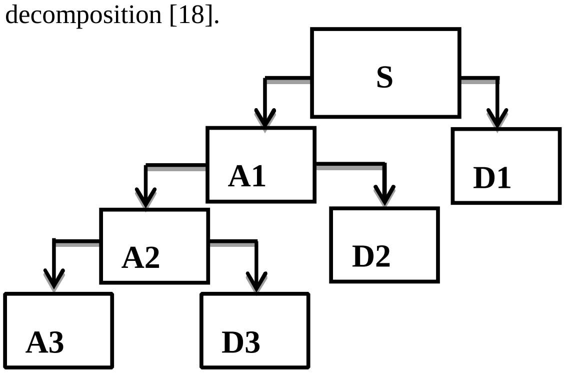

Figure 3: Three-level decomposition of an 'S' signal by the wavelet method [17]

S= A1+D1
= A2+D2+D1
= A3+D3+D2+D1

As mentioned earlier, there are several wavelet families which are: Haar, Daubechies, Symlet, Coiflet, biorthogonal, Meyer, Morlet.
In our application we have chosen a family of almost symmetric wavelets: the Symlets. Figure 4 represents the symlets of order 2 and 3.

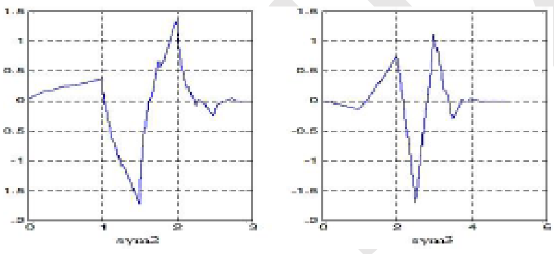

Figure 4: The Symlets of order 2 and 3

Application of the Wavelet Method

We applied the wavelet method on a 400 kV transport line with a length of 128 km (Figure 5). The aim here is to detect the presence or absence of defects afterwards the classification of the fault type.

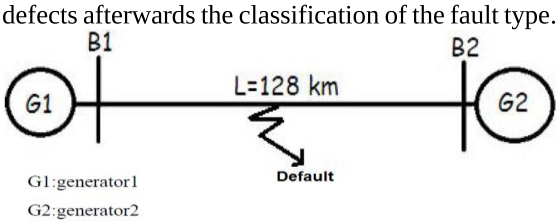

Figure 5: The single-line diagram of the network studied

The simulation model of the system was developed using the MATLAB/Simulink software.

The Parameters of the Model

Length of the line = 128 kilometres
The Source voltages:

- Source 1: V1 = 400 kV
- Source 2: V2 = 400 kV

Source impedance (both sources):

- The positive order impedance = 1.31 + j15.0
- The zero order impedance = 2.33 + j26.6

Transmission impedance:
The positive order impedance = 8.25 + j94.5
The zero order impedance = 82.5 + j308
The positive order capacity = 13 nF / km.
The zero order capacity = 8.5 nF / km.
Frequency = 60 Hz.

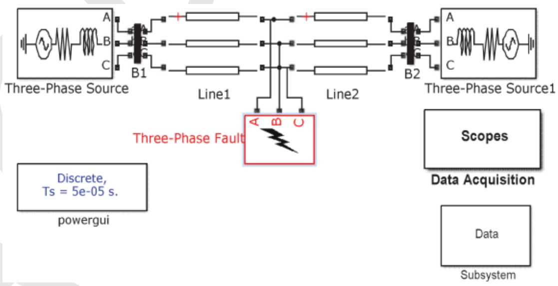

Figure 6: Model SIMULINK of a transmission line of (128km, 400kv)

Analysis of Results

In Figure 7 we see on the first figure that the three currents have sinusoidal forms. The details d1 and d2 resulting from the wavelet analysis do not detect any abnormality so the network is healthy.

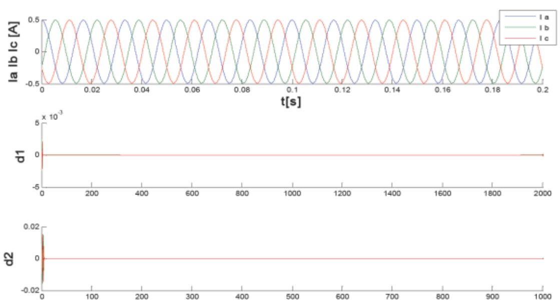

Figure 7: Results of the wavelet analysis of a healthy transport line (without defects)

Figure 8 shows current waveforms at the occurrence of a single-phase fault between phase A and ground G. It can be seen from the first figure that the current in phase A increases sharply relative to the other two phases due to the presence of the fault.

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Moreover, the wavelet analysis of the three current signals I_a, I_b and I_c makes it possible to detect the presence of a defect, which can be seen on the second and third figures which represent the details calculated by the wavelets method.

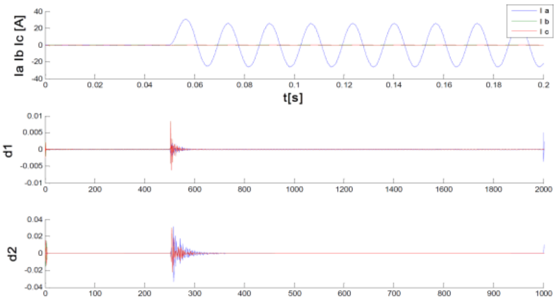

Figure 8: Detection of a single-phase fault by the wavelet method

After using the wavelet method for detection we will now use it for classification of defects i.e. determine the default type that occurs on the line. Here we recall the types of possible faults:

Single-phase fault between phase and earth.

1. Two-phase fault between two phases.
2. Two-phase ground fault between two phases and earth.
3. Three-phase fault.

The classification of the defects was made on the basis of the percentage of the energy levels of the various signals I_a, I_b and I_c analyzed by the wavelet method. The comparison of the different energy levels of the various faults easily indicates and differentiates the type of fault which occurs on the transmission line.

Method of Phasors

For the phase of localization we will study a conventional method based on the synchronized data coming from two ends of the line to be protected, using the approach of phasors [4].

This method contains the two main steps:

- The first step: Estimation of phasors.
- The second step: Estimating the defect distance using the estimated phasors.

As mentioned above, the phaser is a complex number which characterizes a period of a given signal and which can be estimated by several methods, among which is the method of Fourier Analysis.

Location of Defects by Phasors

Among the algorithms used, in the localization of the defects based on the synchronized data of the two ends of the line by the approach of the phasors, we opted for the least squares algorithm [4].

Let the following diagram represent a three-phase line with two ends with a defect at the point F:

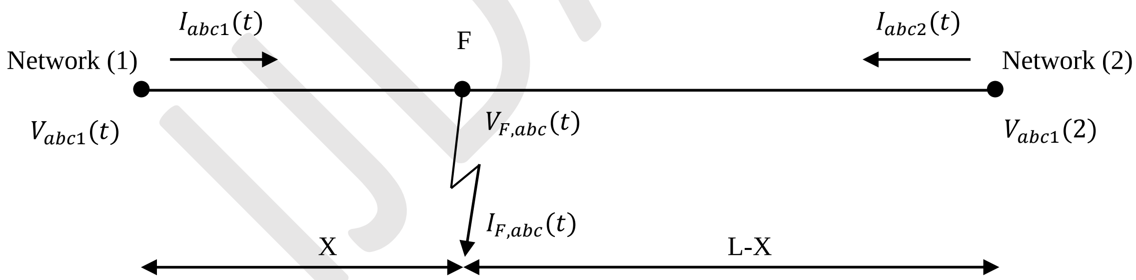

Figure 9: Three-phase line with a point F defect

V. Basic Elements of Neural Networks

- W. James (1890, American Psychologist): Introduces the concept of associative memory and proposes an operating law for learning neural networks later known as the "Hebb law".
- J. Mc Cullochet W. Pitts (1943): Leave their names to a modeling of the biological neuron (a neuron with binary behavior). They are the first to show that simple neural networks can perform logical, arithmetic and symbolic functions.
- D. Hebb (1949, American physiologist): Explains the conditioning in animals by the properties of the neurons themselves (e.g. the famous Pavlovian behavior). He also proposes a law to modify the properties of connections between neurons.
- F. Rosenblatt (1957): Develops the Perceptron model. He builds the first neurocomputer based on this model and applies it to the field of pattern recognition (technological prowess for the time).
- B.Widrow (1960, automatician): Develops the Adaline model (Adaptive

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LinearElement), close to the Perceptron model but whose learning law is different. This one is at the origin of the algorithm of back propagation of the gradient very used for the learning of the Multilayer Perceptrons.

- M. Minsky and S. Papert (1969): Publish a book that highlights the limitations of Perceptron, especially the impossibility of solving nonlinear problems. After their work, funding for research on artificial neural networks stops and researchers turn to artificial intelligence and rule-based systems.
- 1967-1982: Hollow period for artificial neural networks. Research focuses on related fields such as adaptive signal processing, neurobiology, pattern recognition, and so on.
- J. J. Hopfield (1982, physicist): Profits from a certain disillusionment of the artificial intelligence (hit with serious limitations) and presents a theory of the functioning and the possibilities of the networks of neurons. He explains in a book the structure and law of learning a network of neurons corresponding to an expected result. This model is still very much used today for optimization problems.
- 1983: The Boltzmann machine is the first known model capable of satisfactorily processing the identified limitations of Perceptron. But the practical use proves difficult, the times of convergence being considerable.
- 1985: The gradient back propagation algorithm is developed. It is a learning algorithm adapted to multilayer neural networks.
- Currently: Multi-layer networks and gradient back-propagation remain the most studied and most productive at the application level [19].

VI. Conclusion and Perspectives

In this paper, we have studied the use of neural networks as an alternative method for the detection, classification and localization of faults on transmission lines. In a first place we used conventional methods which are the method of wavelets and that of phasors. Then, we used the ANN to demonstrate their superiority over conventional methods. The methods employed use the stretches and the measured currents of the two ends of the line.

To demonstrate the efficiency of ANN we have studied two applications: a simple transmission line and a double transmission line with all the possible defects on these two lines and different ANN have been proposed for each case.

The implementation of all the programs developed in this work was carried out under the environment and with the SIMULINK toolbox and the artificial neural network toolbox of MATLAB. These developed models can subsequently be implemented in a digital relay for possible use in real time.

In this work, we used the back-propagation learning algorithm as a possible extension of this work, it would be very useful to analyse other possible architectures of neural networks and make a comparison between them such as Radial Basis Function (RBF) Neural Network and Support Vector Machines (SVM). Another extension of interest to our work is the implementation of approaches developed on digital relays and to test their performance in real time.

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